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The Human Energy Cost of Certain Household Tasks

By
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SUMMARY

This study is an attempt to measure objectively the human energy cost of housework. By means of a Benedict knapsack apparatus, the oxygen consumption of women engaged in household tasks was measured, and their total energy metabolism calculated. Fifteen women served as subjects for 1181 experiments. The tasks studied were paring potatoes, laundering, ironing, and mixing batters and doughs.

On the basis of the results obtained, the following tasks, requiring less than 100 per cent more energy than resting, are classified as light work: paring potatoes; ironing, either standing or sitting; and beating a batter. Moderately heavy tasks, 100 to 150 per cent over resting, are kneading dough, and most laundry tasks where modern equipment is used. Heavy tasks requiring 150 to 200 per cent over resting are rinsing clothes, hanging them up from a basket on the floor, washing clothes by hand, and wringing with a hand-power wringer.

THE HUMAN ENERGY COST OF CERTAIN HOUSEHOLD TASKS¹

By VeNona W. Swartz

INTRODUCTION

There are in this country approximately twenty-eight million homemakers.² A study of the occupations of this great number of women is well worth while, if suggestions can be made which will lighten their labor or shorten their hours of work.

Time studies have been made in a number of states to find out how many hours a week the homemakers were spending at their work. The time spent on the different operations was separately classified as to care of food, care of textiles, care of children, home management, etc. Recommendations were made for methods of saving time.

On the other hand, this bulletin reports an attempt to find how much human energy a woman uses in her homemaking duties. There have been in the past but few scattered studies in this field. Benedict and Johnson, of the Nutrition Laboratory in Boston, reported in 1919 on the energy expended by 14 to 25 subjects engaged in different sorts of tasks. The household tasks studied were hemming, dusting, and sweeping. A few years later, Langworthy and Barott of the Office of Home Economics, using two subjects, studied knitting, crocheting, darning, sewing by hand and with motor and foot driven machines, dressing an infant (doll), washing³ and ironing towels,⁴ sweeping and washing the floor,⁵ and washing dishes.⁶ In 1922, GaGirns and O'Brien studied the energy expenditure of eight subjects during bread making, machining, and floor polishing. A study closely related to housework was made in 1928 by Benedict and Parmenter on the energy required by 12 subjects for ascending and descending stairs. Swartz, in 1929, reported on the energy required by 10 subjects to use a vacuum cleaner.

¹ The work herein reported was carried on as Home Economics Project No. 4, under Purnell funds at the State College of Washington Agricultural Experiment Station. A comprehensive, detailed report of the experimental work has been prepared, and a bound copy can be borrowed from the State College of Washington Library, at Pullman.

² United States census, 1930.

³ Without water.

⁴ Cold iron.

This study proposes to extend the work previously done and to repeat some of the problems already studied under more natural conditions. The tasks studied and reported here are paring potatoes, laundering, ironing linen napkins, and mixing batters and doughs. In the work on preparing potatoes, the effect of the standing and sitting position was compared. An attempt was made to compare labor-saving devices with older devices and methods in the laundry study. The work on ironing included a comparison of sad and electric hand irons and electric ironers; irons of different weights; and ironing boards of

Table 1. Physical Characteristics of Subjects

Subject	Occupation	Age years	Height inches	Weight pounds	Surface area sq. m.
A*	Teacher	25-26	66	124-133	1.63-1.69
B	Teacher	25	60	109	1.45
C	Student	21	63	108-111	1.49-1.50
D	Homemaker	32	63	113	1.52
E	Teacher	33	68	179	1.95
F	Teacher	30	65	121	1.60
G	Student	25	67	142	1.74
H*	Student	21-22	64	126-131	1.59-1.63
I	Student	23	69	159	1.88
J	Student	19	69	152	1.83
K*	Student	22-23	67	140-143	1.72-1.75
L*	Student	21-22	66	149-141	1.76-1.72
M	Student	20	63	139	1.65
N	Student	22	65	117	1.58
O	Student	20	71	150	1.87

* Tests made over period of two years.

different heights. Batters and doughs were mixed at tables of different heights to find the effect of table height on the energy expenditure of the worker.

From two to seven women subjects were used for each test. Most of the subjects were college students; a few were faculty members, and one was a homemaker. Their physical characteristics are given in Table 1. Subjects I and J were sisters, and subjects L and N, twins.

HOW ENERGY IS MEASURED

The principle employed for measuring the energy consumed is a familiar one, and is as follows: The body is constantly engaged in a process of absorbing oxygen and throwing off carbon dioxide. This process goes on at a faster or slower rate depending on the activity

of the body. A person breathes more rapidly when running than when standing or sitting still. He breathes more slowly when sleeping than when lying awake because the demands of his body are then at their lowest.

When conditions are standardized, the activity of the body can be measured quite accurately by determining how much oxygen is absorbed per minute, or how much carbon dioxide is produced. The oxygen measurement is generally believed to give a truer picture of the body activity than the carbon dioxide measurement, therefore it was the oxygen consumption that was measured in these tests.¹ A given quantity of oxygen was measured into rubber bladders previous to the tests, and the time required to consume it was measured while the subject performed the task in question.

Apparatus. The apparatus used² consisted of a metal framework that rested on the subject's shoulders and was held securely by straps around her waist. The mouthpiece, valves, rubber tubes and soda lime can were supported by this framework. The parts carried by the subject weighed approximately seven and one-half pounds. A picture of the apparatus is given in Figure 1. Figure 2 shows the apparatus in place for an activity test.

A rubber mouthpiece in the subject's mouth was connected, on the right, to a one-way flutter valve, through which the exhaled air left the body. A similar valve at the left of the mouthpiece permitted air to come to the subject but did not allow the exhaled air to leave by that route. Thereby circulation in one direction was assured. Rubber tubing connected to the right hand valve carried the expired air to the bottom of a soda lime can, supported by the metal framework back of the subject's shoulders. There it passed through a layer of approximately an inch and a half of soda lime, losing its carbon dioxide, and into a rubber bathing cap which covered the top of the soda lime can. The bathing cap, to which was attached an indicator button, expanded when the subject exhaled. When the subject inhaled, the air was drawn down from the bathing cap, through part of the soda lime, and reached the subject through the left hand tube and inlet valve.

Method. At the beginning of an experiment, the whole system was full of oxygen-rich air. For a brief period of two and one-half to three minutes, oxygen was admitted from a rubber bladder through a petcock at the bottom of the soda lime can, so that at the end of

¹The most scientifically accurate method involves the measurements of both the gases and the computation of the respiratory quotient. For these tests we assumed a respiratory quotient of 0.82, which is the average for persons at rest 12 to 18 hours after the last food has been eaten.

²Built by Warren E. Collins, Inc., 555 Huntington Ave., Boston, Mass.



Figure 1. Benedict knapsack apparatus.



Figure 2. Benedict knapsack apparatus in position.

that time, the little indicator-button on the bathing cap just touched a fixed metal plate supported by the soda lime can. Then the measured quantity of oxygen was admitted and the timing begun. When the indicator button no longer touched the plate on a full exhalation, the period was over. A second measured quantity was always used immediately after the first, as a check on accuracy. The quantity of

oxygen measured into the bladders was such that it would last about three minutes for one complete test. Between each two experiments the apparatus was removed to rest the subject. Each complete test required nine to twelve minutes.

Calculation. The results are reported in two ways, in calories per square meter of body area per hour, and in per cent above resting. These figures were derived as follows from the experimental data: The oxygen absorbed per minute in liters, corrected to standard temperature and pressure, multiplied by 4.825,¹ multiplied by 60, and divided by the surface area of the subject in square meters,² gave the energy expenditure in calories per square meter of body area per hour. The difference, between this value and the corresponding value for lying relaxed and quiet on a bed, divided by the latter value, gave the percentage above resting occasioned by the activity.

No Measurement of Fatigue. It should be remembered that it is total body activity that is measured by this apparatus, and not fatigue. Fatigue is a subjective state, very difficult to measure, even approximately, and no attempt was made in this study to determine how much fatigue was caused by the tasks. It is possible for a very light task to be extremely fatiguing. The following data, therefore, do not justify any comparisons as to the tiring effect of the task studied. The information here given relates merely to the energy needs of the body as affected by certain activities. It is usually true, however, that an activity that demands a large expenditure of energy is also tiring.

Classification of Work. An arbitrary classification of tasks according to their energy demands on the body has been set up as follows:

Light.....	under 100 per cent above resting
Moderately heavy.....	100-150 per cent
Heavy.....	150-200 per cent
Very heavy.....	200-300 per cent
Extremely heavy.....	above 300 per cent

RESTING

The energy required for the performance of a given task is made up of several distinct parts. First, the energy necessary for muscular tension and for the continuous body processes such as respiration, circulation, secretion, and excretion is constant from hour to hour and from day to day in a normal person. This is called resting metabolism. Then, in addition, there is the energy required for the activities in which the person engages. The digestion of food, particularly protein

¹ The caloric value of a liter of oxygen, assuming an R. Q. of 0.82.

² Calculated from the Dabois height-weight formula.

foods, calls for a further small expenditure of energy. For each person who serves as a subject in energy metabolism studies, it is necessary to determine the resting metabolism, to be used as a basis of comparison. This value is subtracted from the total cost to give the net cost of the activity being studied.

Tests were made on each subject while lying on a comfortable bed after one-half hour of rest. No tests were run within two hours of any meal, or within five hours of a meal containing much protein. In addition, three subjects were studied while sitting relaxed on a kitchen chair, two while sitting on a stool, and three while standing quietly. These are of interest for comparison with working activities. The results on these resting tests are given in the following sections, along with the results on the activities with which they were obtained.

PARING POTATOES

Conditions of Tests. Metabolism tests were made with the subjects paring potatoes in a study of the effect of body posture on the energy requirement of a task. The subjects were tested at work while sitting on a kitchen chair, while sitting on a kitchen stool, and while standing. The position on the stool was the only uncomfortable one. With a high stool, it was not possible to put the knees under the table, hence for this experiment the subjects turned their bodies at the waist in order to work over the pan on the table. Many housewives would hold the pan in their laps, but this position was not tested. When the subjects sat on the chair, they held the pan in their laps. In every case the potatoes were washed and placed in a pan of water before the test, and an ordinary paring knife was used.

Results. The results of the tests on paring potatoes, as well as some resting data, are given in Table 2. The conclusions from these tests are as follows:

1. On the average, paring potatoes requires about 50 per cent more energy than resting.
2. Energy cost by individuals varies from 25 to 90 per cent above resting. One cannot successfully predict the energy expenditure of one individual from the average.
3. Paring potatoes while sitting on a chair averages 43 per cent over resting.
4. Paring potatoes while standing averages 50 per cent above resting.
5. Paring potatoes while sitting on a stool averages 54 per cent over resting.

Table 2. Energy Cost of Paring Potatoes as Compared with Resting

Kind of activity and subject	Number of tests	Average cal./sq. m./hr.	Per cent above resting	Kind of activity and subject	Number of tests	Average cal./sq. m./hr.	Per cent above resting
Resting				Paring potatoes, chair			
A	14	32.4		A	10	46.1	42.3
B	5	33.4		B	3	44.8	34.1
C	3	33.7		C	3	42.4	28.8
D	3	29.3		D	2	48.4	65.2
E	2	29.0		E	2	47.1	62.4
F	3	27.4		F	2	39.6	44.5
G	3	34.8		G	2	43.5	26.0
Av.				Av.			42.8
Sitting on kitchen chair				Paring potatoes, stool			
A	11	37.1	14.5	A	10	50.3	56.8
B	2	33.8	1.2	B	3	49.5	48.2
C	6	37.3	10.7	C	4	44.0	30.6
Av.			8.9	D	2	55.4	89.0
Standing, rested				E	2	48.2	66.2
A	11	37.1	14.5	F	1	40.0	46.0
B	2	36.6	9.6	G	2	49.3	41.7
C	6	37.8	12.2	Av.			54.1
Av.			12.1	Paring potatoes, standing			
Standing, tired*				A	11	46.5	43.5
A	9	37.6	16.1	B	3	50.0	49.7
Sitting on kitchen stool				C	3	45.4	34.8
A	7	37.0	14.2	D	2	50.5	72.4
C	3	35.5	5.3	E	2	46.7	61.0
Av.			9.8	F	2	42.8	56.2
				G	3	46.5	33.7
				Av.			50.2
				Paring potatoes, standing, tired*			
				A	10	50.2	54.9
				B	1	53.2	59.3
				Av.			57.1

* After two or more hours of standing.

6. Two subjects, standing, require 57 per cent for pants when tired; but when they are not tired, they require only about 47 per cent over resting.

7. There is no justification, from an energy standpoint, for sitting uncomfortably on a high stool. Instead, sitting comfortably on a ordinary kitchen chair is to be recommended.

LAUNDRY PROCESSES

Laundry work is of such a complex nature that it must of necessity be broken into its component parts for satisfactory study. There are fully 15 different processes in the task of washing clothes. Of these 15, some are of such short duration and others are of such a nature that they are not easily measurable, but seven were selected for study. Variations of these seven gave a total of 11 tasks, each studied separately. A fairly complete picture of the energy cost of any method of home laundering can be obtained from these 11 studies, combined with a knowledge of how much time is spent on each task. It is hoped that these data will help to determine which devices and methods are truly energy-saving.

Conditions of Tests. The following tasks were carried on continuously throughout the test period:

1. Putting up and removing the clothes line.
2. Washing clothes by hand, rubbing on a metal washboard. No wringing.
3. Wringing clothes by hand.
4. Wringing clothes with a hand-power wringer mounted on a galvanized tub 34 inches from the floor.
5. Wringing clothes with an electric wringer.
6. Drying clothes in an electric extractor, which included lifting the wet clothes into the extractor, standing still during the spinning, and lifting the damp clothes back into the water.
7. Rinsing clothes, consisting of stirring the clothes about and lifting them up and down in the rinse water.
8. Hanging clothes, with basket on floor, consisting of bending over from waist to pick up clothes and clothes pins from basket on the floor and moving basket about as necessary.
9. Hanging clothes from utility table when it was not necessary to bend over to reach clothes and pins. Table easily moved about.
10. Emptying washing machine, consisting of filling pail from faucet near the floor with two gallons of water, carrying six feet, and emptying into a laundry tub.
11. Cleaning laundry equipment, consisting of wiping the washing machine and scouring the laundry tubs.

Kind of activity and subject	Number of tests	Average cal/sq. m./hr.	Per cent above resting	Kind of activity and subject	Number of tests	Average cal/sq. m./hr.	Per cent above resting
Resting	A	32.3		I	2	76.1	139
	C	34.4		J	2	76.4	138
	H	35.0		K	3	91.3	137
	I	31.8		L	3	80.5	131
	J	35.0		Av.			126
Washing clothes by hand	K	31.3		A	3	88.5	174
	K	36.4		C	3	81.8	138
	L	102.7	218	H	3	79.3	127
	A	95.2	177	I	3	92.3	190
	C	87.1	149	J	3	85.9	145
Wringing clothes, by hand	H	101.0	218	K	3	86.8	173
	I	99.0	183	L	3	101.0	177
	J	101.1	218	Av.			161
	K	98.7	171	A	3	84.9	163
	L	191	191	C	4	70.3	106
Wringing clothes, by hand	Av.			Av.			135
	A	77.3	141	A	3	96.9	200
	C	74.1	115	C	3	82.5	140
	H	78.2	123	H	3	84.4	141
	I	79.4	160	I	3	91.4	187
Wringing clothes, with electric wringer	J	77.5	121	J	3	92.3	164
	K	85.0	167	K	3	116.1	265
	L	89.7	143	L	3	106.3	192
	Av.		138	Av.			184
Wringing clothes, with hand-power wringer	A	106.2	229	A	3	69.4	116
	C	90.3	164	C	4	62.5	82
	H	191	191	H	3	71.6	106
	I	66.0	104	I	3	70.8	123
	J	60.4	76	J	3	72.9	111
Wringing clothes, with electric wringer	C	70.9	103	K	3	83.6	163
	H	69.4	118	L	3	82.2	153
	I	62.6	79	Av.			119
	J	66.1	108	A	3	38.3	72
	K	74.5	105	C	3	70.6	105
Drying clothes in extractor	L	99	99	H	3	89.3	178
	Av.			Av.			159
	A	70.3	118	A	3	75.6	149
	C	64.5	88	C	3		
	H	71.5	105	Av.			

The clothes used were a five and one-half pound load of garments and linens representative of a family washing. Tepid, or warm water was used in the tests. No soap was used.

Results. The results of these laundry tests are given in Table 3. It will be seen that seven of the tasks are light or moderately heavy, requiring less than 150 per cent above resting. These are wringing clothes with electric wringer, 99; hanging clothes from utility table, 118; drying clothes in extractor, 125; putting up and removing line, 135; wringing clothes by hand, 138; emptying washing machine, 139; and cleaning laundry equipment, 149 per cent above resting. The others are heavy tasks, requiring 150 to 200 per cent above resting: rinsing clothes, 161; hanging clothes with basket on the floor, 184; washing clothes by hand, 191; and wringing clothes with a hand-power wringer, 197 per cent above resting.

Wringing. Of special interest is a reconsideration of the figures on the various methods of wringing clothes. On the basis of energy per square meter of body area per hour, wringing clothes with an electric wringer requires the least energy, 99 per cent above resting; drying clothes in an extractor takes more, 125 per cent; wringing clothes by hand comes third, 138 per cent; while wringing clothes with a hand-power wringer averages 197 per cent above resting. These data are on the basis of a time unit of use, i.e., for each minute or hour of use, the hand-power wringer requires twice as much human energy as the electric wringer.

On the other hand, the energy for these operations can also be computed on the basis of a unit of accomplishment, namely, wringing one load of clothes weighing five and one-half pounds. The figures given in Table 4 show that on this basis, as well as on the other, the human energy cost of using hand-power methods is definitely greater than the energy cost of using electric equipment. To wring a load of clothes by hand requires about twice as much energy as to use an electric wringer or extractor, while to use a hand-power wringer requires about three times as much energy per load as to employ electric equipment.

Table 4. Energy Cost of Wringing Clothes and Amount of Water Remaining

Method	Per cent above resting	Calories per sq. m. of body area per load	Pounds of water remaining in load
By hand	138	4.7	7.7
Hand wringer	197	7.5	4.7
Electric wringer	99	2.3	4.9
Electric extractor	125	2.6	4.8

Conclusions.

1. Laundry tasks are, on the whole, moderately heavy to heavy tasks, requiring energy 100 to 200 per cent in excess of resting requirements.

2. There is much variation between the energy requirements of different subjects performing the same task. What one person may do with an expenditure of 88 per cent over resting, may cost another person 187 per cent.

3. The use of the hand-power wringer is not justified except that it removes water more completely than does wringing by hand. The hand-power wringer requires approximately 60 per cent more energy than any other method of wringing clothes.

4. The energy expenditure of hanging clothes can be cut from 184 per cent above resting, when the basket is on the floor, to 118 per cent above resting, by putting the clothes on a wheeled table. A small wagon that can easily be drawn about or a box may be substituted. This saving amounts to approximately 35 per cent.

Ironing Napkins. On the subject of ironing, the effect was studied of the following factors on the human energy required for the task: height of ironing board, sitting compared to standing, use of electric ironers, weight and size of iron, and method of placing iron on board when not in use.

For the sake of simplicity and greater accuracy in controlling conditions, flatwork was selected, rather than garments. Medium weight linen dinner napkins were used, dampened by a standard method and allowed to stand for at least one hour before ironing. The method of ironing was kept constant, and the time of ironing was controlled at two minutes per napkin. Change in any one of the factors could easily change the total energy requirement, so that under home conditions we should expect to find energy costs differing widely from those found in the laboratory. Nevertheless, controlled conditions were necessary in the laboratory in order to make sure that the differences observed between two irons, for example, were due to the irons and not to some variation in the method of ironing.

Height of Ironing Board. Table 5 shows that on the average, less energy is spent in ironing at a high ironing board than at one of the recommended height. The recommended height for each subject was from one to two inches lower than her correct table height, which was one where she could stand erect and place her palms flat on the table without bending her elbows. The high board was two inches higher, and the very high four inches higher than the recommended or normal board. If a lower board had been tested, it is reasonable to suppose that the energy cost would have been greater than with a normal board.

Table 5. Effect of Height of Board on Energy Required for Ironing Napkins

Subject	Resting	Ironing napkins					
		Cal per sq. m. per hr.			Per cent above resting		
		Normal board	High board	Very high board	Normal board	High board	Very high board
A	32.1	58.7	55.4	55.4	82.9	72.6	72.6
C	34.5	53.7	52.5	53.4	55.6	52.2	54.8
H	35.0	64.1	64.8	60.7	83.2	85.2	73.4
I	31.8	60.0	60.7	58.8	88.7	90.8	84.8
J	35.0	61.8	59.7	57.8	76.6	70.6	65.2
K	31.8	68.9	62.9	58.4	116.7	97.8	83.6
L	36.4	62.5	62.0	57.2	71.7	70.3	57.2
Av.		61.4	59.7	57.4	82.2	77.1	70.2

A few supplementary experiments with a pressure-measuring device gave some explanation of why the energy cost is less with a high board. The pressures exerted by subjects A and K, three tests each, were respectively 0.5 and 1.0 pounds less at a high board than at a medium or normal board.¹ At a low board they were respectively 0.5 and 1.5 pounds more than at a medium board. These results are in the same order that should be expected from the energy measurements on these women. The other two subjects with whom pressure measurements were made showed no marked difference between high and medium boards and only a little increase in pressure at the low board over that exerted at the medium board. These subjects, H and L, also showed practically no difference between the energy expended at a high board and that used at a medium board (Table 5).

These considerations make it doubtful if any true conclusions can be drawn from metabolism figures regarding the best ironing board height, from the standpoint of energy consumption. It can be said truly, though, that at a high board women generally use the same or less pressure and the same or less energy than at a normal board, and at a low board they use more of both than at a normal board.

However, to exert a given pressure at a high board would almost certainly require more energy than to exert the same pressure at a

¹ Pressure exerted in pounds:

Subject	High board	Normal board	Low board
A	8.6	9.1	9.6
H	8.3	8.1	8.4
K	8.6	9.6	11.1
L	8.6	8.4	8.8

Table 6. Effect of Sitting and Standing on Energy Cost of Ironing Napkins

Subject	Year	Sitting, chair*		Sitting, stool†		Standing‡		Saving over standing	
		No. tests	Per cent above rest	No. tests	Per cent above rest	No. tests	Per cent above rest	chair	stool
A	1932	-	—	9	66	12	97	—	32
A	1933	3	49	3	54	4	75	35	28
C	1932	-	—	4	42	10	52	—	19
H	1933	3	62	4	67	3	91	32	26
K	1933	3	77	3	85	3	87	12	2
L	1933	3	59	3	70	3	72	18	3
Av.			62		64		79	24	18

* Ironing board as low as possible, 27 inches high.

† Ironing board 32.5 inches high.

‡ Ironing board normal height for all except C, high for her.

medium or low board. This was not measured, but is merely a prediction.

Sitting, Compared to Standing. As shown in Table 6, by sitting on a chair to iron, the subjects saved from 12 to 35 per cent of the net energy used in standing to iron. Sitting on a stool to iron saved less energy, or 2 to 32 per cent of the net energy required for ironing while standing. Table 6 shows that the average savings for all the subjects are 24 per cent for the use of the chair, and 18 per cent for the stool. The position on the stool was less comfortable than on the chair.

In both the sitting positions the ironing surface was relatively higher than in any of the standing tests. If the same relative height could be employed when sitting as when standing, in all probability the saving gained by sitting would be much greater. It is physically impossible to have the board as low when the subject is seated as when she is standing.

Ironers. The results given in Table 7 show that the average energy cost of using three rotary electric ironers is 45 to 47 per cent above resting. This is appreciably less than the 62 per cent required by sitting and using a hand iron, and is even more of a saving over the 70 to 80 per cent required by standing to iron.

Table 7. Effect of Use of Electric-Ironer on Energy Cost of Ironing Napkins

Subject	Rotary ironers I and II		Rotary ironer III		Flat-press ironer	
	No. tests	Per cent over rest	No. tests	Per cent over rest	No. tests	Per cent over rest
A	29	51	5	38	3	60
C	5	39	-	-	-	-
H	-	-	3	44	-	-
K	-	-	5	58	-	-
L	-	-	3	47	-	-
Av.		45		47		60

One subject, using a flat-press ironer, required 60 per cent above resting, on three trials. More data are necessary to justify any conclusions concerning the energy cost of using that type of ironer, although it will probably prove to be slightly more energy consuming than the other type.

Kind of Iron. The figures in Table 8 show that the kind of iron has little effect on the energy cost of ironing. There seems to be a little difference in favor of the lightest weight iron, although only one subject, H, showed it definitely. Also, only one subject, A, showed any difference between the 4.6 pound iron with the straight handle and the same iron with the sloping, "fatigue-proof" handle. Two irons weighing approximately six pounds gave the same results.

Table 8. Effect of Kind of Hand-Iron on Energy Cost of Ironing Napkins*

Kind of iron	Weight pounds	Subject	No. of tests	Per cent above rest
Electric, chrome-plated, 1000 W.	3.5	A	3	65.6
		H	3	81.3
		K	4	85.1
		L	3	70.6
		Av.		75.2
Electric, chrome-plated, 1000 W. Straight handle	4.6	A	3	78.6
		H	3	90.7
		K	4	96.5
		L	3	73.6
		Av.		84.9
Same iron as above but with sloping handle	4.6	A	3	58.7
		H	3	89.5
		K	5	95.5
		L	3	74.8
		Av.		79.6
Electric, nickle-plated, 625 W.	5.9	A	4	75.1
		H	3	91.0
		K	3	86.9
		L	3	71.8
		Av.		81.2
Electric, chrome-plated, 1000 W.	6.2	A	3	65.4
		H	3	86.7
		K	3	89.8
		L	3	81.9
		Av.		81.0

* Medium height board used.

Pressure measurements with these irons of different weights indicated that two of the four subjects on whom measurements were made, A and K, used the most net pressure with the lightest iron and

the least with the heaviest iron.¹ Net pressure is the total pressure on the board minus the weight of the iron. These subjects made up for the lack of weight of the light iron by increasing the pressure they applied to the iron. A third subject, H, used the same pressure with the three irons, while the results of the fourth subject, L, are from one test only with each iron, and hence are not conclusive.

In addition to the results given in Table 8, 10 tests were made on subject A while ironing with two sad irons, weighing three and four pounds. The energy cost was found to be 94 per cent above resting. Walking five steps to the stove to change irons every two minutes was included in the test.

Placing Iron. Energy studies were used to answer the question of the best position for leaving the iron when not in actual use. Table 9 gives the energy cost of putting the iron in the positions indicated, eight times a minute. It shows that turning the iron on its side is

Table 9. Effect of Method of Setting Iron on Board on Energy Required

Subject	On stand		On heel		On side	
	No. tests	Per cent above rest	No. tests	Per cent above rest	No. tests	Per cent above rest
A	3	35.2	3	35.2	4	29.0
C	3	30.4	4	32.5	4	25.5

slightly more economical of energy than either setting it on a stand or tipping it up on its heel rest, about 27 compared to 33 per cent above resting. There is no difference evident between the energy cost of using a stand and a heel rest.

Effect of Fatigue. When a feeling of fatigue was present, subject A expended energy 83 per cent above resting to do the ironing task that required 73 per cent when she was not tired. This indicates that she spends somewhat more energy when tired than when not tired. With subject C, a few experiments indicate the opposite for her. When tired, she used energy 49 per cent in excess of resting; but when not tired, ironing with the same iron and board, she used 55 per cent

¹ Net pressure exerted in pounds:

Subject	6.2 lb. iron	4.6 lb. iron	3.5 lb. iron
A	2.4	3.6	4.3
H	1.8	2.0	1.9
K	2.5	2.7	2.9
L	0.7	2.4	2.1

above resting. Without further work on more subjects it is not possible to predict the effect of fatigue on energy cost of tasks.

Conclusions.

1. Ironing napkins is a light task, requiring energy approximately 70 to 80 per cent above resting.
2. Less energy is used at a high board than at a normal or medium one, probably because less pressure is exerted.
3. Sitting on a chair to iron saves 24 per cent, and sitting on a stool to iron saves 18 per cent of the energy over resting required to stand and iron.
4. Ironing on a rotary electric ironer cuts the human energy expenditure for ironing to about 45 per cent over resting.
5. The weight or finish of the irons does not seem to affect the energy expenditure of all the subjects in the same manner. One subject spent somewhat less energy using a three and one-half pound iron, while three other subjects did not. A sloping handle on an iron decreased the energy expenditure for one subject, while it did not for three others. One subject spent energy 94 per cent above resting in the use of two sad irons, in contrast to approximately 75 per cent for the use of other irons.
6. Turning the iron on its side when not in actual use saves about 15 per cent of the energy above resting required to lift it to a stand, or turn it on its heel-rest.
7. The affect of fatigue on the amount of energy required for a given activity was opposite in two subjects. One required more energy when tired; the other required less.

MIXING BATTERS AND DOUGHS

A short study was made of the effect of the height of the table on the human energy required for two representative kitchen tasks, beating and kneading. Three table heights were used for each subject: medium, or one where she could stand erect and rest her palms flat on the table without bending her elbows; low, which was two inches lower than medium; and high, which was two inches higher than medium. Flour and water mixtures of suitable composition were used for beating and kneading.

Results. The results given in Table 10 show that with one exception, the height of the table in the range studied made no difference in the energy expenditure of the subjects while beating. The exception, subject M at the low table, used energy 95 per cent above resting, while at the medium table she used only 75 per cent above resting. For her, then, raising the table two inches saves 21 per cent in energy. No other of the seven subjects showed this saving.

Table 10. Effect of Height of Table on Energy Cost of Beating and Kneading
(Three to five tests each)

Subject	Resting	Beating						Kneading					
		Cal. per sq. m. per hr.			Per cent above rest			Cal. per sq. m. per hr.			Per cent above rest		
		Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
A	34.3	52.4	52.2	52.2	52.7	52.2	52.2	76.2	69.3	72.0	122	102	110
H	33.7	46.4	46.5	47.1	37.7	38.0	39.8	91.7	82.5	81.4	172	146	143
K	32.4	46.8	46.8	46.1	44.5	44.5	39.2	76.5	71.8	71.3	136	132	120
L	33.4	48.0	47.9	47.3	43.7	43.4	41.7	73.4	69.1	62.0	120	107	86
M	35.7	69.7	62.6	64.5	95.2	75.3	80.6	81.8	79.6	81.9	129	123	130
N	33.7	48.6	49.3	50.0	44.2	46.3	48.4	76.5	75.0	74.4	127	123	121
O	34.9	57.7	57.3	55.3	65.4	64.2	55.5	77.4	72.5	69.8	122	108	100
Av.					54.8	52.0	51.5				133	119	116

In kneading, on the other hand, every subject but one required more energy at the low table than at any other height.

Conclusions.

1. Beating a mixture of about the consistency of cake batter is a light task, requiring energy about 50 per cent above resting.

2. For most subjects the table height does not affect the energy required for beating. The adjustment to a low table is made in the angle of the elbows.

3. Kneading a mixture of the consistency of bread dough is a moderately heavy task, averaging 115 to 130 per cent above resting.

4. With a medium or high table, less energy is required for kneading than with a low table. Adjustment is made to a low table by bending the back and stooping the shoulders.

5. Two subjects required more energy to knead at a high table than at a medium one, while two required less.

GENERAL CONCLUSIONS

Critical, scientific thought and experimentation on household tasks have shown that some methods and devices are labor-saving while others are needlessly wasteful of energy. There is no reason why an excessive amount of energy should be spent at housework. It is far wiser to spend a minimum of energy on the mechanics of homemaking and thereby have some strength left for recreation and family relationships.

It should be remembered, in applying the work reported here, that there is much variation between persons in their energy requirements for the same tasks. In estimating the daily calorie needs of a person, nothing but an approximation can be expected from the use of published tables of average expenditures of energy, for one person may expend a great deal more energy on a given task than another. Only by actual measurement of the individual's energy consumption can accuracy of a high degree be obtained.

It should also be noted that no measurement was made of the fatigue arising from the tasks studied. The fatigue is probably roughly proportional to the energy expended, but it certainly cannot be said to be in direct ratio. A measurement of the fatigue caused by these tasks would be very desirable.

To summarize, a graphic statement of the average energy costs of certain household tasks is given below in Figure 3.

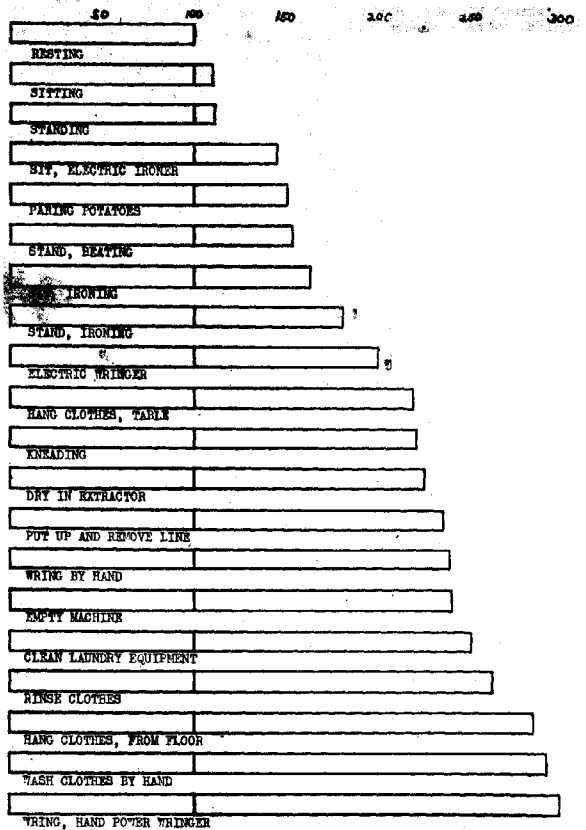


Figure 3. Average energy cost of resting and certain household tasks.

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